LOUDOUN COUNTY LANDFILL

INTERIM REPORT IV

for

INSTALLATION OF SITE L WELLS
L-1, L-1D, L-2, L-3, L-4, L-4A, L-4D, L-5, L-6, L-7, L-7D, L-8,
L-9, L-10, L-11, L-11D, L-12, L-13, L-14, L-15-P1, L-15-P2, L-16,
L-17, L-18, L-19, L-20, L-21, L-21D, L-22-P1, L-22-P2,
L-23, L-23D, L-24, L-25

November, 1992

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LOUDOUN COUNTY LANDFILL

SITE L

MONITORING WELLS AND GEOTECHNICAL BORINGS INSTALLATION AND TESTING

November, 1992

I. INTRODUCTION

A. Background and Summary

Emery & Garrett Groundwater, Inc. (EGGI), in association with Groundwater Systems, Inc. (GSI), was retained by the County of Loudoun, Virginia, to install a series of geotechnical borings and monitoring wells on a land parcel designated as Site L (Figure 1). Site L is located directly south of the existing Loudoun County Sanitary Landfill and is the proposed location for a new County landfill and solid waste management facility. Geotechnical borings and monitoring wells were installed, developed, and tested to evaluate the subsurface conditions beneath this proposed facility. EGGI and GSI completed all work tasks according to the specifications outlined by the County of Loudoun Department of Environmental Resources (DER), and as modified by DER personnel during the drilling and installation of borings and wells.

All field work was completed by EGGI/GSI between August 10 and October 14, 1992, and included the following:

1) Installation of thirty-one monitoring wells: 23 "shallow" wells, 6 "deep" wells, and two stacked piezometers (two piezometers in each of two borings). "Shallow" and "deep" are terms used to differentiate wells adjacent to one another and do not reflect actual depth ranges of the wells. A summary of all monitoring well data is provided in Table I.

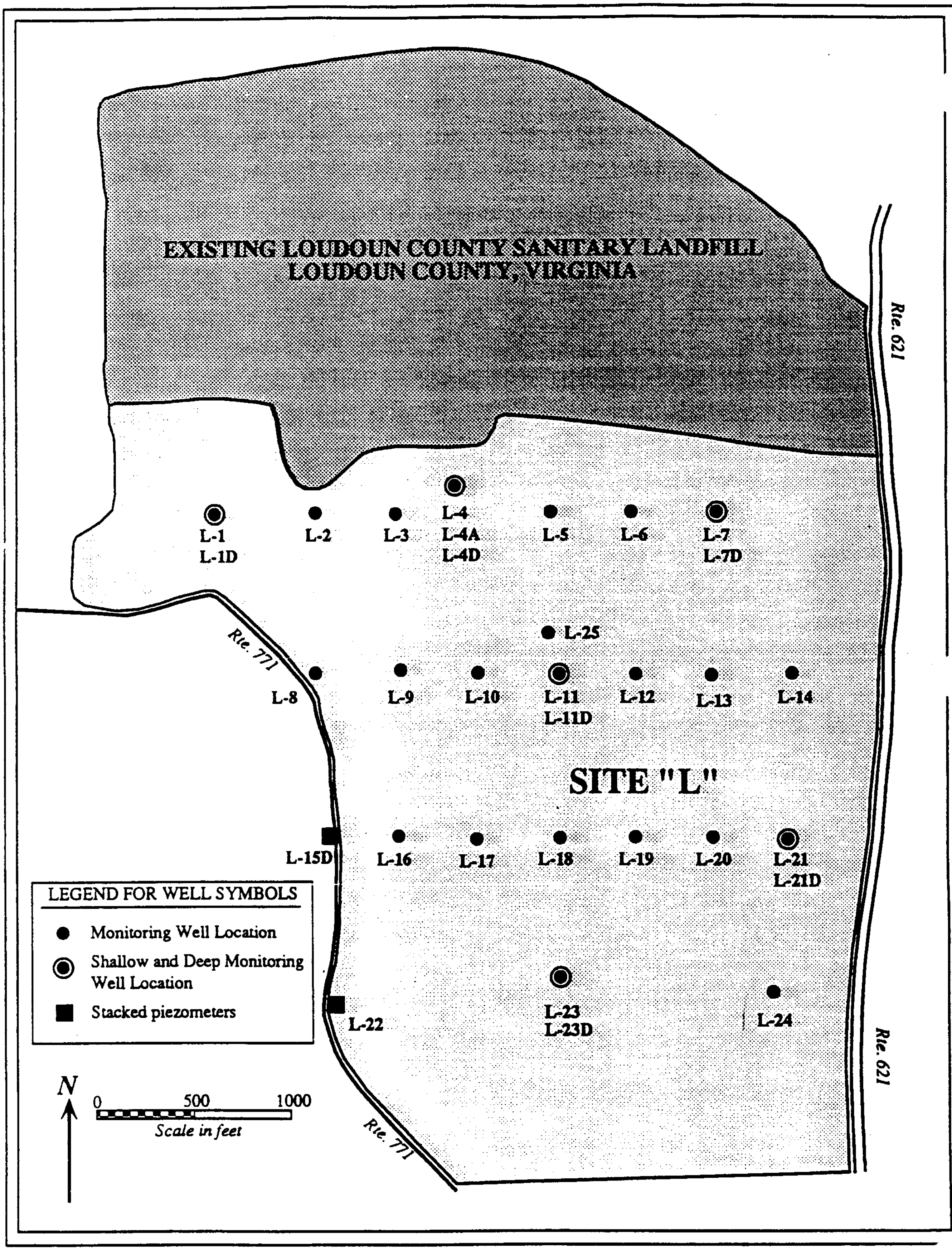

FIGURE 1 -- LOCATION OF MONITORING WELLS WITHIN PROPOSED SITE "L" LANDFILL FACILITY.

WELL ID	DATE DRILLED	DRILLING METHOD [4]	TOTAL CONSTRUCTED WELL DEPTH (feet)[1]	SCREEN SECTION (feet)[1]	CONTINUOUS SAMPLING INTERVAL (attempted &/or collected)[2]	WATER LEVEL DEPTH (feet)[3]	ESTIMATED YIELD (GPM)
L1	10/1/92	Air Rotary	150	130-150	*	132.57	<<1
L1D	8/19/92	Air Rotary	180	160-180	85-105	133.23	<1
L2	8/20/92	Air Rotary	140	120-140	60-80	117.65	>10
L3	8/31/92	Combination	70	50-70	35-55	29.30	<1
L4	9/8/92	Air Rotary	85.4	65.4-85.4	*	61.32	>10
L4A	9/25/92	Combination	75	55-75	*	61.54	<1
L4D	8/25-27/92	Air Rotary	123	103-123	25-45	60.65	50
L5	8/12/92	Air Rotary	90	70-90	20-40	52.40	<1
L6	8/11/92	Air Rotary	81.5	61.5-81.5	45-65	74.33	1-2
L7	8/14/92	Air Rotary	71	51-71	*	62.81	<10
L7D	8/13/92	Air Rotary	135	125-135	25-45	62.66	<5
L8	9/28/92	Air Rotary & NQ Core	125	105-125	**	108.82	>10
L9	9/2/92	Air Rotary	75	55-75	35-55	42.86	<1
L10	9/3-4/92	Combination	76	56-76	30-50	50.34	<1
L11	9/1/92	Combination	75	55-75	*	33.22	120
L11D	9/17-18&21/92	Combination	126	106-126	10-30	34.11	>1
L12	9/21/92	Auger	53	33-53	10-30	20.90	<1
L13	9/22/92	Auger	36	16-36	0-20	25.92	<1
L14	9/22-23/1992	Auger	50	30-50	0-20	31.72	<1
L15-P1	9/14/92	Air Rotary	189	119-189	*	101.16	>1
L15-P2	9/14/92	Air Rotary	103	83-103	50-70	94.35	>1
L16	9/10/92	Combination	86	66-86	30-50	56.34	<1
L17	9/16/92	Air Rotary	83	63-83	15-35	42.32	<5
L18	9/24/92	Air Rotary	84	64-84	30-50	65.75	50
L19	9/23-24/92	Auger	60	40-60	5-25	37.90	1
L20	9/30/92	Auger	57	37-57	20-40	40.77	<1
L21	9/29/92	Auger	50	30-50	0-20	20.38	>5
L21D	9/29/92	Combination	85	65-85	*	17.34	>5
L22-P1	9/15/92	Air Rotary	150.5	130.5-150.5	*	81.13	<1
L22-P2	9/15/92	Air Rotary	100	80-100	35-55	99.19	<1
L23	9/23/93	Air Rotary	84	64-84	30-50	57.56	20
L23D	9/21-22/92	Air Rotary	125	105-125	*	57.22	20
L24	9/16/92	Air Rotary	64	44-64	5-35	37.30	<5
L25	10/6/92	Air Rotary	60	40-60	***	36.96	>12

[1] Feet below ground surface.

[2] * Not required because of continuous sampling in adjacent well.

** Intercepted bedrock in targeted sampling interval; continuous NQ core from 50-63'.

*** Not required.

[3] Feet below top of casing (TOC) as recorded 10/12/92.

[4] Combination = Air rotary rig; augers installed to stabilize hole.

TABLE I

2) Development of twenty-nine monitoring wells was accomplished by using submersible pumps to "surge and pump" each well.

3) Collection of over 375 split-spoon samples. These samples were used to generate detailed lithologic logs of the subsurface geologic conditions. Over eighty-five of those split-spoon samples were collected using hollow-stem augers. Standard penetration tests were conducted on selected split spoon samples via hollow stem augers.

4) Twenty-two saprolite samples were collected with shelby tubes or brass-lined split-spoons to preserve the integrity of in-situ hydraulic characteristics. These twenty-two samples were submitted to Golder Associates, Inc. of Mt. Laurel, New Jersey, for laboratory testing of permeability (ASTM Test Method D5084) and porosity.

5) Changing Head Tests (falling head and rising head) were completed on eight monitoring wells located within Site L. The hydrogeologic data collected from these tests were submitted to the DER for use in calculating hydraulic conductivity values for subsurface materials existing beneath the proposed facility.

B. General Geologic Setting

The Loudoun County Sanitary Landfill is located within the geologic depression known as th Culpeper Basin. The Culpeper Basin was the site of sediment deposition and volcanic activity, relatea to the opening of the Atlantic Ocean, approximately 200 million years ago (Mesozoic time). Lee (1979/1980) and Lee and Froelich (1989) show that the region underneath and immediately adjacent to Site L and the existing landfill are underlain by interbedded conglomerates (Goose Creek Member of the Catharpin Formation) and sandstones with subordinate siltstones (Catharpin Formation). The Culpeper Basin is bounded by the Bull Run Border Fault to the west.

Sedimentological analyses of the conglomerate (Lee and Froelich, 1989) indicates that the sediments were deposited in a high energy, fluvial environment with anastomosing/braided stream channels. Clasts in the conglomerate were mostly derived from the older (mostly Paleozoic time) rocks west of the Culpeper Basin and include quartzite, greenstone-greenschist, and minor limestone. In addition, clasts of red siltstone to sandstone derived from older sedimentary rocks within the Culpeper Basin are present. The clasts are supported in a matrix which is poorly sorted, comprised of feldspar and quartz, and cemented with carbonate. Voids left by the dissolution of the carbonate cement and limestone clasts give this rock the propensity to develop channels which can enhance groundwater movement. Saprolite derived from this conglomerate is commonly silty to clayey, and contains variably altered clasts of sandstone, siltstone, and greenstone-greenschist (See Appendix 1 for details). Quartzite and bull quartz clasts are essentially unweathered, whereas all limestone clasts and the carbonate cement of the conglomerate are entirely absent in the saprolite. Weathering of all clasts generally decreases with depth as unweathered bedrock is approached.

II. COMPLETION OF GEOTECHNICAL BORINGS AND MONITORING WELLS

A. Drilling Methods

Specifications developed by the Loudoun County DER required the use of two drilling techniques for the collection of geotechnical information and the installation of monitoring wells. Air rotary drilling was used to install most of the borings and wells due to the inability of a hollow stem auger rig to obtain the depths required to intercept groundwater and the problems augers have when encountering the quartzite boulders in saprolite. A unique combination of rotary and hollow-stem augers was used in some instances to overcome difficulties associated with the natural geologic variability encountered at the investigation site.

1. Air Rotary Drilling

A Schramm T-450-H, air rotary drilling rig was used for installing twenty-five monitoring wells at Site L. The use of an air rotary rig (as opposed to a mud rotary unit) enhanced the detection of trace moisture and the water table, as well as providing a "clean" method for the collection of representative samples from the borehole. This drilling method also minimized the potential for contaminant introduction since no foreign water, etc., was introduced into the borehole during drilling operations. Prior to setting up over a particular drilling location, the entire drilling rig and its tools were decontaminated with a high-pressure rinse using drinking-quality water from a hydrant specified by the Loudoun County DER.

Drilling commenced using a six foot auger flite with a 12-inch outside diameter. This was left in the ground during subsequent drilling to prevent near surface collapse and was withdrawn after drilling to provide adequate space for proper installation of the protective casing and grout. An eight-inch air-hammer bit was used to drill the remainder of each boring. Water table elevations were estimated through projection from nearby wells and observations during drilling. When drilling approached the anticipated water table, great care was taken to notice any change in character of the drill cuttings. Subtle changes in the moisture content of chips and their granular nature was often the only indication that the water table had been intercepted, especially in portions of the site with very low permeability materials. To confirm the depth of the water table, drilling was often suspended for several minutes to several hours to allow the anticipated free water surface to seep into the borehole.

Air rotary drilling advances the bit with no support on the walls of the borehole. In unsaturated unconsolidated saprolite or bedrock this presents no problems, as the hole stays open throughout its length. However, in saturated unconsolidated saprolite, the borehole is less competent and caving of the borehole is possible. In many circumstances, especially in the "deep" wells, excessive caving required construction of a temporary borehole wall, which was accomplished by using steel casing or hollow-stem augers. If steel casing was used, the hole would usually be expanded to 10 inches in diameter to allow for the installation of eight-inch casing. This casing would be lowered to competent rock or to the specified bottom of the drilled hole. The monitoring well would then be built inside the casing as the casing was lifted several feet at a time. Alternatively, a combination of traditional drilling techniques allowed hollow-stem augers to be rotated into the ground using the air-rotary rig. Augers then maintained the open hole while the well was being constructed. Five foot sections of augers were removed as the well construction progressed towards the ground surface.

Bedrock encountered during drilling operations created significant challenges to well construction. The transition zone from unconsolidated saprolite into competent bedrock is often a soft zone, where bedrock has been thoroughly weathered, but the clay minerals which make the saprolite cohesive have not yet developed. This transition zone often collapsed when penetrated during drilling and, in most cases, was cased-off to allow the construction of the monitoring well to be accomplished. Casing was also required when a significant volume of water was encountered in bedrock fractures ... as the removal of large volumes of water from the bedrock would cause caving/erosional problems in the overlying saprolite.

2. Hollow-Stem Auger Drilling

Hollow-stem augers are used in many geotechnical applications to obtain representative samples and perform standard penetration tests. A series of five-foot long auger flites (8-inch outsiddiameter) are connected to one another and rotated into the subsurface. A plug on the inside of the leading auger forces the cuttings up the outside of the augers to the ground surface. At required intervals, the plug can be removed so a split-spoon or shelby tube sampler can be driven into the undisturbed material beyond the bottom of the augers. Standard penetration tests are performed while driving the sampler with a 140 pound hammer dropping 30 inches. "Blow counts" (the number of hammer drops) are reported for each six-inches of penetration over a two foot interval (i.e., 4-6-6-8).

At Site L, six borings (L-12, L-13, L-14, L-19, L-20 and L-21) were completed using the hollow-stem auger drilling technique. Each of these standard penetration tests were conducted at specified intervals. Original specifications required penetration tests for L-11, but those requirements were waived in the field by DER personnel. Wells were constructed inside the auger flites. The flites were raised incrementally as construction of the well progressed.

B. Sampling Procedures

Although sampling procedures generally followed those outlined by the DER prior to the start of drilling, site-specific hydrogeologic conditions required that minor modifications to sampling be made. Split spoon samples were taken at 5 foot intervals to the depth of the water table. These samples were supplemented with split spoon samples taken at 2.5 foot intervals within zones designated by the DER for continuous sampling. The continuous sampling zone extended 20 feet below the anticipated base of the proposed landfill. All of these split spoon samples (over 375) were bagged, labelled and transferred to the Loudoun County DER for grain size analysis and storage. The occurrence of competent quartz clasts sometimes resulted in poor sample recovery or no recovery at all. Where possible, missed samples were obtained at the same depth during drilling in adjacent wells (i.e., in paired well situations). DER personnel often waived the requirement for collecting saturated samples when caving problems during drilling threatened the successful completion of a well in the boring. Therefore, a limited number of split-spoon samples were recovered from beneath the water table.

Samples of saprolite were collected with shelby tubes (or split-spoons with brass liners) in 16 boreholes from within the "continuous sampling interval" designated by DER (Table II). Tube samples allow the collection and storage of an undisturbed portion of subsurface material. Samples were immediately sealed with paraffin melted onto each end of the tube, capped with plastic, and taped

TABLE II

GEOTECHNICAL TESTING AND SAMPLE INTERVALS
LOUDOUN COUNTY LANDFILL - SITE L

WELL #	DEPTH INTERVAL (feet)	PERMEABILITY RESULTS (cm/sec)	POROSITY RESULTS	PENETRATION TESTS*
L-2	68-70	3.6 X 10-7	0.37	
L-3	42-45	4.6 X 10-6	0.49	
L-3	52-55	2.8 X 10-6	0.39	
L-4D	16-18	4.6 X 10-5	0.39	
L-4D	30-32	9.4 X 10-5	0.36	
L-4D	42.5-45.5	4.6 X 10-4	0.34	
L-4D	61-62	3.9 X 10-5	0.37	
L-5	45-47	4.3 X 10-4	0.47	
L-6	65-67.5	2.6 X 10-4	0.34	
L-7D	45-47.5	2.9 X 10-6	0.31	
L-8 **	50-63	***	***	
L-9	41.5-42.5	1.4 x 10-4	0.37	
L-10	36.5-37.5	3.3 x 10-6	0.37	
L-11D	10-11	4.6 x 10-5	0.39	
L-11D	18-19	3.2 X 10-4	0.36	
L-11D	25-26	9.5 x 10-4	0.32	
L-11D	35-36	3.3 X 10-5	0.28	
L-12	19-21	2.4 x 10-6	0.39	Yes
L-13	10-12	4.0 X 10-5	0.40	Yes
L-14	***	***	***	Yes
L-16	45-47.5	2.0 x 10-6	0.37	
L-17	22.5-25	1.5 x 10-4	0.42	
L-19	17.5-20	2.8 X 10-6	0.40	Yes
L-20	30-32.5	1.3 X 10-4	0.47	Yes
L-21	***	***	***	Yes
L-23	41-42	2.0 x 10-5	0.33	

* Penetration counts are reported on the lithologic logs - Appendix 1.

** Core Sample collected with a 2-inch NQ core.

*** Not required.

to prevent the loss of any natural moisture content. The samples were shipped to Golder Associates, Inc. of Mt. Laurel, New Jersey, for laboratory analysis of permeability (using ASTM Test Method D5084) and porosity (Table II, Appendix II).

Rock "cuttings" were collected at ten foot intervals when drilling through bedrock, so that lithologic records for each well would be complete. Rock "coring" had to be completed in only one well, L-8, where competent rock was encountered within the "continuous sampling zone." Thirteen feet of continuous core was collected between 50 and 63 feet, using a two-inch diameter, NQ wire-line coring system. As a surprise to all, saprolite was again encountered at 63 feet and continued to the bottom of L-8 at 140 feet suggesting that a very large unweathered boulder was encountered between 50-63 feet.

Water levels in two wells (L-19 and L-24) were intercepted before the bottom of the original continuous sampling interval. Therefore, in order to satisfy engineering requirements and DER specifications, new wells were drilled nearby to allow continuous sampling of the saprolite above the water table.

C. Geologic Logs

Each monitoring well installed by EGGI/GSI was supervised and logged by an EGGI geologist. All collected split-spoon samples were examined and described by EGGI geologists before being transferred to the DER for storage and laboratory analyses. Field observations were recorded on a detailed lithologic description sheet, prepared by EGGI geologists and approved by DER personnel prior to the start of drilling operations. A copy of each boring information sheet was submitted to the DER after the conclusion of drilling along with any field notes taken by the geologist on site. The recorded field notes and boring information sheets were used to prepare detailed lithologic logs of each boring (Appendix I).

All boreholes penetrated red to brown, clayey, silty saprolite derived from conglomeratic parent material (Appendix I). Fine, primary bedding structure was preserved in a number of the split-spoon samples. In several borings, thin (2 to 4 inch) sandy layers are interlayered with the more typical silty/clayey saprolite. Clasts within the saprolite were variably weathered mafic schist, red sandstone and siltstone, and unaltered gray and black quartzite and white bull quartz. The degree of weathering of the mafic schist and sedimentary clasts decreased with depth as unaltered bedrock was approached. No competent limestone clasts or carbonate cement remained in the unconsolidated materials underlying Site L.

D. Monitoring Well Construction

All wells were installed to meet DER specifications as closely as possible, however, unique hydrogeologic conditions at a few of the monitoring well sites required minor divergences from the original specifications. During the drilling process, continuous communication was maintained between EGGI, GSI and the DER (Mr. Rich Ryan) to ensure that the monitoring wells were constructed according to specifications or that, when necessary, appropriate and acceptable modifications were made. The objective for most of the well installations was to place the screened interval so that sufficient standing water would be present in each monitoring well year round for observation purposes. Seasonal variations will occur in water table elevations and it should be recognized that observed water levels may fluctuate by as much as five feet or more during a given year. Final construction details are presented in Appendix I and Table I.

"Shallow" and "deep" are terms used to differentiate wells drilled adjacent to one another which are screened at different intervals relative to the elevation of the water table (for instance L-7 is "shallow" and L-7D is "deep"). The terms <u>do not reflect actual total depths or depth ranges of the wells</u>. A "shallow" well was defined in the specifications as being screened between 10 and 30 feet below the water table at the time of drilling. A "deep" well was to be screened between 40 and 70 feet below the water table at the time of drilling. However, specific hydrogeologic conditions encountered during drilling were considered before setting the screen according to the pre-determined intervals. Changes to original specifications (i.e., total depth and screened intervals) were based on natural on-site conditions, such as the elevation of the water table, depth to bedrock, and depth to fractures. All changes to original well specifications were approved by DER personnel prior to final well construction.

Monitoring wells were installed using 4-inch (inside diameter), schedule 40, threaded PVC pipe with 20 feet of 10-slot screen at the bottom (Appendix I). (L-7D was the only exception with 10 feet of screen). The annular space between the borehole and the well screen was filled with 8 x 16 clean quartz sand from the bottom to two feet above the top of the screened interval. Two feet of 40

200 clean quartz sand was placed on top of the sand pack to protect it from the overlying three feet of bentonite seal. The bentonite seal was above static water levels in most cases, so drinking-quality water was added to the annulus of the borehole to hydrate this seal. The bentonite seal was then capped and pressure grouted to the ground surface through the use of a tremie pipe.

The use of continuous pour Portland cement grout to fill the annulus of the borehole created problems in wells L-4 and L-11D. The grout created excessive heat in the boreholes which weakened the PVC and caused it to partially collapse into the two wells. The collapse occurred where significan void spaces existed above the water table. When these large voids were filled with substantial amounts of grout, an exothermic reaction occurred (at the time the grout set up) which released excessive heat. Because this happened above the water table, the heat was not dissipated and the PVC pipe absorbed the heat. PVC at 140° F retains only 22% of the strength it has at 73.4° F. The heat caused the PVC to soften, whereupon the casings collapsed under their own weight. Wells L-4 and L-11D are still usable for water level measurements and for sampling with a bailer, but a 4-inch submersible pump cannot be placed in the well. Well L-4 was replaced with well L-4A as a result of the collapse; monitoring well L-11D may be replaced at a future date.

E. Stacked Piezometer Installation

Wells L-15 and L-22 were designed to be installed similarly to all the other wells at Site L. However, very low permeability conditions below the water table existed which did not allow the determination of water tables during the drilling process. Therefore, the design specifications were modified upon boring completion to include two 2-inch stacked piezometers in each hole with large sand packed intervals separated by grout to hydraulically isolate each screened interval.

L-15 was drilled to a depth of 200 feet per DER request, penetrating bedrock at 71 feet below ground (Appendix I). The water table was anticipated to be approximately 97 feet below ground surface, but no definitive determination of water table depth could be made due to the very low permeability of the bedrock. Drilling operations were terminated for twelve hours to allow water to enter the borehole, although there was no way of determining where the water would enter. Water levels rose at a rate of 1.5 feet per hour during the shutdown period. DER personnel decided to construct paired piezometers in the boring to obtain water level information only. A soft zone in the bedrock was penetrated at 112 feet, so it was assumed that water was entering the borehole at this interval. Therefore, DER personnel instructed the driller to install screen from 119 to 189 feet with continued sand pack to 110 feet. The upper piezometer was screened from 83 to 103. The screened intervals were separated by a bentonite/grout/bentonite seal (Table I; Appendix I).

Similarly, L-22 was a very low yielding well drilled in bedrock. Water table was expected to be intercepted at 81 feet and the total well depth of the well was to be 111 feet. Bedrock was intercepted at 69 feet with a soft zone encountered from 73 to 81 feet. Per DER request, the hole was deepened to 150 feet in an attempt to intercept a water-bearing fracture zone. Twenty-six hours after drilling had terminated, only three feet of water had flowed into the well. DER personnel specified screened intervals to be placed from 130.5 to 150.5 feet (sand pack up to 110 feet) and 80 to 100 feet. The screened intervals were separated by a bentonite/grout/bentonite seal (Table I; Appendix I).

III. DEVELOPMENT OF MONITORING WELLS

A properly designed development program is the final step in the installation of a functional monitoring well. Fine material within the sand pack and screen can interfere with water flow through the sand pack. Development removes the fine material which entered the borehole during the well construction process and serves to enhance the hydraulic connection between the well and the saturated formation. A wide variety of development techniques can be applied depending on the type of monitoring wells and their purposes.

At Site L, each well was developed using a combination of surging and pumping. The pumps utilized during well development were 4-inch submersible pumps hung on black polyethylene tubing. During pumping, a surging action was accomplished by lifting the pump up and down, creating turbulence within the sand pack. This turbulence helped to move fine material from the sand pack area to the borehole and then was removed from the well via pumping.

Care was taken during well development to prevent contamination of the subsurface. Because only the existing water is used in these techniques, contamination of the wells through the addition of external fluids was prevented. Introduction of contaminants was further prevented by a bottom check valve on the pump which prevented the return of water into the well after it passed through the pump. Before development with this pumping method, decontamination procedures were followed to minimize the risk of cross-contamination. The submersible pump was rinsed with drinking water applied with a high pressure jet. New black polyethylene tubing was dedicated for use in every well being developed to eliminate the possibility of cross-contamination via tubing surfaces.

IV. FALLING AND RISING HEAD TESTS

The County of Loudoun Department of Environmental Resources requested that falling and rising head tests be conducted on eight of the new monitoring wells. With the exception of Well L-12, water levels in monitoring wells being tested were allowed to equilibrate following well development to ensure that stabilization had occurred at the natural piezometric head.

A. Design and Materials

Falling and rising head tests allow the in-situ hydraulic conductivity of the aquifer near the borehole to be determined using a single, small diameter borehole. The tests are initiated by causing an instantaneous change of water level in the well and monitoring the change in water level elevation (head) as the water level recovers to pre-test levels.

During this study, the instantaneous change in water level was created by lowering a "pig" (a 3-1/2 inch O.D., six foot long, cylindrical piece of *stainless steel*)into a borehole to displace water. The pig has a 1-1/4 inch cylindrical opening parallel to its long axis through which a pressure transducer cable can travel independent of pig movement. This design was incorporated by EGGI at the request of DER personnel to provide consistency with past consultant's work at the landfill and to provide instantaneous displacement of water during the test. Stainless Steel 304 was used to construct the pig; this is the same material most commonly used in water well screens because of its resistance to corrosion. The pig displaces 0.35 cubic feet of water, so when lowered into a 4-inch well, water levels are displaced by a maximum of 4.01 feet. When the pig is lowered into the well, the water level rises rapidly, simulating the addition of a volume of water into the well (falling head tests). Water level changes are then monitored using a pressure transducer connected to a data logger. Once water levels have re-equilibrated to pre-test levels, the pig is lifted out of the water, creating an instantaneous lowering of the water table in the well and a subsequent rise in water levels until pre-test conditions are once again obtained (rising head tests).

Geokon® pressure transducers and datalogging equipment were used to record changing water levels during these tests. These instruments consist of a pressure transducer which utilizes vibrating-wire technology to transmit pressure readings at pre-determined time intervals to the data logger, where the information is stored for later use. The pressure readings are converted to feet of water over the transducer. For all tests, a 25-psi transducer was used to ensure accurate results at the small ranges of head change. These instruments allow large quantities of data to be collected during the test at very short time intervals. The transducer cables are coated with chemically resistant materials to provide a surface which is easily decontaminated between wells.

B. Decontamination

All of the materials and instruments which were lowered into monitoring wells or the piezometers were decontaminated before each test. Great precautions were taken to prevent any potential pathway for cross-contamination. All testing equipment in contact with the water, including water level probes, transducer cables and the chain used to lower the pig were wiped down with laboratory grade detergent (Alconox®), rinsed with drinking-quality water, dried, and rinsed with distilled water again before being lowered into any well.

The pig was thoroughly cleaned before each test according to a pre-determined sequence of cleaning methods. The pig was kept on a portable table, so that it never came in contact with the ground outside the piezometer casing. The pig was washed using a laboratory grade detergent solution (Alconox®) and dried several times before a first rinse with drinking-quality water. The pig was then rinsed with drinking water a second time and dried thoroughly. Finally, the pig was rinsed with steam distilled water and all of its surfaces were dried to complete the intensive cleaning process. All workers wore latex gloves both for their protection and to maintain the integrity of the decontaminated materials.

C. Testing Procedure

The pig was held just above the water table while the transducer was programmed to accept the static water level in the well as its relative zero reading. Once this zero reading was established, the pig was lowered rapidly beneath the water until its top was one to two feet below the static water level. The bottom of the pig always remained several feet above the pressure transducer.

Water level recordings were programmed at five second intervals at the start of all tests. Depending on the response of the well, sampling intervals were changed to obtain a representative number of readings for the analysis.

When the pig submerges, the instantaneous change in water level recorded by the transducer shows seemingly erroneous values which cannot be explained by the displacement attributable to the volume of the pig. This occurs for two reasons. First, as the pig is lowered into the water, the displaced water must travel through the narrow space between the pig and the well wall. Thus, the displaced volume of water fills the six foot narrow opening very quickly and then fills the entire well volume on top of the pig. This causes water levels to be higher than expected for the first one to two seconds. The second reason is an instantaneous pressure increase in the water below the pig due to the momentum of the pig hitting the water. The transducer records this short pulse of increased pressure as increased water levels. These artificially increased water level impacts have dissipated within a few seconds of the test and have no implications on the hydrologic analyses of these slug tests. If the first reading was greater than 4.01 feet, the maximum displacement, then a value of 4.01 feet should be applied.

In addition, the rapid changes in water levels are significantly impacted by the presence of unsaturated sand pack outside the screened portion of the well. At the time slug tests were performed, one of the monitoring wells had a portion of the screen exposed above the static water table (Well L-14). Upon insertion of the pig, the sand pack absorbed some of the displaced water very quickly. This resulted in an initial rapid decrease in water levels (i.e., 0-2 seconds) which is not representative of the formation's hydraulic conductivity. Similarly, during the first several seconds of the rising head tests, the sand pack rapidly loses water and fills the wells much faster than the formation actually releases water. This occurrence should be noted when analyzing the falling/rising head data and for any well whose screened interval is exposed in the unsaturated portion of the borehole.

D. Data Compilation of Falling Head and Rising Head Tests

Data compilation began with the elimination of all the extraneous data from each test. Excessive data was collected to confirm that full recovery had taken place and that the transducer and data logger were operating properly. The data included in the appendices has been reduced to only those necessary for the analysis of hydraulic characteristics of the borehole (Appendix III).

Minor modifications were made to the original data to correct for small changes in the relative zero reading of the transducer. For instance, the raw data for some tests does not complete recovery to the original zero reading. However, the data did recover to a stable reading, usually between 0.01 and 0.04 feet from its original zero position. During these tests, the transducer cable moved slightly (less than four hundredths of a foot) from its original position when the pig was lowered or raised. During the data compilation process, a constant was added to these data to correct the actual data to the original zero reading. This will have no bearing on the results of the analysis, but it provides a much clearer presentation of the collected testing data.

Well L-3 was very slow in responding to the falling head test. Because of the slow response, the DER waived the requirement for a rising head test. The falling head test was continued for 1374 minutes, nearly one full day, and 75% of full recovery had taken place before the test was terminated.

The falling and rising head tests on Well L-12 were conducted soon after the completion of well development. Recovery from well development had been monitored but it was discovered that water levels had not fully recovered to natural ambient conditions. The results of L-12 falling and rising head tests were corrected for water level changes related to the recovery of the well from development. The laws of superposition in groundwater flow allow the impact of the recovery to be removed from the raw data, preserving the actual data from the falling head test. The corrected water levels only accounted for a small amount of recovery due to previous development.

The first set of changing head tests run on Well L-19 were also conducted soon after well development showed poor results due to interference effects caused by previous development on the well. To ensure accurate results, the falling and rising head tests were run a second time and only those results are presented in Table III and Appendix III.

LOUDOUN COUNTY SANITARY LANDFILL
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RESULTS OF FALLING AND RISING HEAD TESTS ON SELECTED MONITORING WELLS

WELL	TEST	DATE	ELAPSED TIME (MINUTES)	PERCENT RECOVERY	MAXIMUM DISPLACEMENT (FEET)*
L-1D	1st Falling	10/9/92	213	100	4.01
	2nd Falling	10/13/92	170	100	3.39
L-3	1st Falling	10/6/92	1374	75	3.21
L-5	1st Falling	10/5/92	141	100	4.01
	1st Rising	10/5/92	222	98	3.82
L-9	1st Falling	10/7/92	325	97	3.50
	1st Rising	10/7/92	316	94	3.51
L-12	1st Falling	10/8/92	420	100	3.47
	1st Rising	10/8/92	204	95	3.55
L-14	1st Falling	10/8/92	121	99	4.01
	1st Rising	10/8/92	139	97	2.98
L-17	1st Falling	10/1/92	28	99	3.26
	1st Rising	10/1/92	24	99	3.40
	2nd Falling	10/1/92	21	99	3.69
L-19	2nd Falling	10/13/92	27	100	3.39
	2nd Rising	10/14/92	29	98	3.40

* 4.01 feet is the maximum theoretical displacement using or existing equipment. If the first transducer reading exceeded 4.01, then the maximum displacement was presented as 4.01.
An attempt was made per DER request to conduct Falling and Rising Head Tests using a minimum of three feet of water displacement.

TABLE III